



INTRODUCTION

.1 SUMMARY

The Burroughs B 5500 Information Processing System is a medium-scale computer system that is suitable for both scientific and commercial data processing. Flexibility in the choice of system configurations results in monthly rentals that range from \$16,700 to \$160,000. Typical B 5500 systems, however, fall within the \$20,000 to \$35,000 rental range.

The B 5500 system is an upgraded, improved version of the highly unconventional and imaginative B 5000 system, which was first delivered in March, 1963. Burroughs announced the B 5500 in October, 1964, as a replacement for all B 5000 systems in the field at that time, and dropped the B 5000, as such, from its product line. In most cases, field modifications permitted on-site conversion of the installed B 5000's to B 5500's.

Changes in hardware have centered principally on the central processor. The processor read access time has been reduced from 6 to 4 microseconds, the execution time of many instructions has been improved, and several new and powerful operators have been added to the repertoire. Software changes included a reworked version of the Drum Master Control Program — designed to take full advantage of the expanded instruction list — and a new Master Control Program that is oriented toward the use of Burroughs' high-performance Disk File. In addition, the COBOL and ALGOL compilers were refurbished to provide improved compilation times and greater efficiency in the generation of machine-language instructions.

It should be noted that the B 5500 is basically a more efficient and, therefore, more productive version of the B 5000; but the B 5500 system retains all the design characteristics that made the B 5000 appear so unconventional when it was announced in 1961. Primary emphasis is still placed on the exclusive use of process-oriented languages (ALGOL, COBOL, and FORTRAN) for coding all user programs. Because of this emphasis, Burroughs has developed hardware and software that is oriented toward fast and efficient compilation, with the hope that no user will feel the need for any machine-oriented languages. The B 5500 also features the capability that has come to be called multiprogramming — the ability to execute more than one independent program concurrently on the same computer system. Both the B 5500's hardware and its Master Control Program (MCP) have been designed specifically to facilitate the support of efficient multiprogramming. Benefitting from several years of experience in this area, Burroughs does not hesitate to market the B 5500 primarily on the basis of its ability to process more than one program simultaneously, leading in most cases to increased job throughput.

Some of the unusual hardware facilities that have been incorporated to help achieve the B 5500's design objectives can be summarized as follows:

- Automatic temporary storage for operands and subroutine parameters is provided by a "stack", which operates on the "last-in, first-out" principle.
- Internal operations can be performed in either the Word Mode, upon 48-bit binary operands, or in the Character Mode, upon strings of 6-bit alphameric characters.
- A common representation is used for integers and floating-point numbers.
- Recursive use of subroutines is largely automatic and unrestricted.
- All machine-language addressing is relative and/or indirect, facilitating program segmentation and relocation.
- The same two registers are used for both indexing and arithmetic operations; no index registers of the usual type are provided.

.1 SUMMARY (Contd.)

- There is effective (but not infallible) storage protection against coding errors, invalid data, and inter-program interference.
- Comprehensive interrupt facilities are provided to detect and service special conditions arising anywhere in the system.
- Each of up to 8 core storage modules can accept or transmit data independently of the other core modules and of the processor.
- Magnetic drums and/or disc files provide rapid-access auxiliary storage for the operating system, compilers, program segments, and data arrays.
- All input-output operations are controlled by independent Input/Output Channels; up to four channels can be connected, and any channel can reference any one of up to 39 peripheral devices in a system.
- A second, virtually independent central processor can be added to any B 5500 system; the two processors share all storage and input-output facilities.

.2 CENTRAL PROCESSOR

The B 5281 Processor of the B 5500 Information Processing System is the control center of a unique arrangement of memory and input-output control units, arithmetic units, and interrupt networks. All internal operations can be performed in either the Word Mode, using 48-bit binary words as operands, or in the Character Mode, using variable-length alphanumeric fields packed eight characters to the word. In the Word Mode, the central processor can perform fixed-point or floating-point arithmetic operations upon single or double word-length binary operands. A variety of logical and comparison operations is also provided in this mode. The Character Mode is designed mainly for data manipulation operations such as editing and scanning. Many processor functions, including addition, subtraction, branching, and table lookups, can be performed in either mode.

A program word consists of four 12-bit "syllables", and each syllable can specify an operation, a relative address, or a literal to be placed in the stack. The Program Reference Table is a relocatable table containing single data items and 48-bit "descriptors," which are used for supplementary control and indirect addressing of data arrays, input-output areas, and program segments. The "stack" consists of the two arithmetic registers (A and B) in the central processor and a relocatable area of core storage; it provides automatic temporary storage of the "last-in, first-out" type for a list of operands and control words. In a multiprogramming environment, each program has its own stack and its own Program Reference Table. Whenever an interrupt occurs during the execution of one program, the contents of the A and B registers and all necessary control information are automatically pushed down into the appropriate stack in core storage; then the Processor transfers control to the Master Control Program, which initiates the processing of the next available program.

Operands in the Word Mode are considered to be 48-bit binary words. The integer part of an operand is represented by 39 bits plus sign, and the octal exponent by 6 bits plus sign. Since the fixed-point part of a B 5500 floating-point number is represented as an integer rather than a fraction, fixed-point and floating-point operands can be intermixed without conversions.

The comprehensive interrupt system informs the Processor when any of 40 possible special conditions arises anywhere in the system. All interrupt conditions are sampled continuously and processed on a priority basis, so that a high-priority interrupt condition (such as a storage parity error) can interrupt the servicing of a lower-priority interrupt condition (such as a free Input/Output Channel).

The Processor of the B 5500 system initiates all peripheral input-output operations by sending a descriptor to a free I/O Channel. The processor is then free to perform its operations independently of the peripheral operation. Up to four "floating" Input/Output Channels can be connected to the B 5500 system, and each Channel can transfer data between core storage and any of the connected input-output devices. Up to four input-output data transfer operations can be performed simultaneously, one per installed I/O Channel, since each I/O Channel functions independently of the others.

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.2 CENTRAL PROCESSOR (Contd.)

The B 5500's Processor includes many improvements to the original B 5000 Processor design. Processor read access time — the total time required to transfer a word of information from core memory to the Processor or an I/O Channel — has been reduced from 6 to 4 microseconds. Syllable overlap techniques have been improved, stack manipulation operations have been accelerated, and 19 new operators have been added. The primary objective in the inclusion of these and other improvements in the B 5500's Processor has been to enable the compilers to generate more efficient object programs and to permit the Master Control Program to perform its program-segment switching and multi-programming control routines more quickly and more effectively.

.3 INTERNAL STORAGE

From three to eight B 460 or B 461 Memory Modules of core storage can be connected to a B 5500 system. Each Memory Module contains 4,096 words, providing a maximum system capacity of 32,768 words, or 262,144 6-bit characters. Each word location consists of 48 data bits and one parity bit and can hold one binary data item (in floating-point or integer form), eight alphanumeric characters, or one program word. The B 460 Memory Module has a memory cycle time of 6 microseconds, as compared with the newer B 461's 4-microsecond cycle time. The B 460 and B 461 are functionally identical, but they cannot be intermixed in the same B 5500 system.

Each core storage module contains its own addressing and read/write circuitry. Operating in conjunction with a switching network called the Memory Exchange, the Memory Modules can transmit data independently of the central processor. Both the Processor and the I/O Channels can communicate with the Memory Modules, but always through the Memory Exchange. Using the maximum B 5500 complement of two Processors and four I/O Channels, six different Memory Modules can be accessed simultaneously. However, only one processor or I/O Channel can access any one Memory Module during any one memory cycle.

The B 430 Magnetic Storage Drum provides an 8.3-millisecond average access time to 32,768 words of auxiliary storage. Up to 1,023 consecutive words can be transferred at the rate of 15,360 words per second. Two Storage Drums can be connected to a B 5500 system. Customers who choose to have their B 5500 system controlled by the Drum Master Control Program (see Section 203:191) must have at least one Storage Drum on-line for MCP and system program residence; two Storage Drums are required for Drum MCP-oriented installations that wish to use COBOL. Use of the Storage Drum provides the MCP with rapid access to program segments, subroutines, and blocks of data.

Burroughs' head-per-track Disk Files can also be utilized as auxiliary storage with the B 5500 system. The Disk File system is a modular on-line storage system that provides storage capacities of up to 960 million characters in modules of 9.6 million characters. Any randomly-addressed block of characters can be accessed within a maximum of 40 milliseconds, and the average access time is only 20 milliseconds. Transfer of information between the Disk File system and the Input/Output Channels proceeds at an average of 100,000 characters per second. From 1 to 1,890 48-bit words of information can be read or written by a single instruction. If two B 5470 Control Units are connected to a B 5500 system, two simultaneous Disk File accesses are possible. Disk File accessing can also proceed simultaneously with computation and up to three additional input-output operations.

In addition to providing the standard random processing capabilities, the use of Disk File storage with the B 5500 system permits the storage of on-line program libraries. The Disk File-oriented MCP (see Section 203:192) is thereby enabled to gain rapid access to all scheduled programs, a fact which adds to the efficiency of the B 5500's multi-programming capability.

.4 INPUT-OUTPUT EQUIPMENT

Most of the input-output equipment offered for use with the B 5500 computer system is conventional in design and performance. Table I lists all of the current peripheral devices (other than the auxiliary storage units described in the preceding paragraphs), together with their principal characteristics. A B 5500 system can include a maximum of two card readers, one card punch, two line printers, three paper tape units (readers or punches), 16 magnetic tape units, and 15 data communications terminal units.

Four different types of data communications terminal units are offered by Burroughs for use with the B 5500 system. The B 481 Teletype Terminal Unit provides buffered interfacing for up to 399 remote Teletype stations; the B 483 Typewriter Terminal Unit can

TABLE I: B 5500 INPUT-OUTPUT DEVICES

Type of Device	Model No.	Name	Characteristics
Punched Card Equipment	B 122	Card Reader	Reads 200 cpm.
	B 123	Card Reader	Reads 475 cpm.
	B 124	Card Reader	Reads 800 cpm.
	B 129	Card Reader	Reads 1,400 cpm.
	B 303	Card Punch	Punches 100 cpm.
	B 304	Card Punch	Punches 300 cpm.
Punched Paper Tape Equipment	B 141	Paper Tape Reader	Reads 5, 6, 7, or 8-level tape at 500 or 1,000 char/sec.
	B 341	Paper Tape Punch	Punches 5, 6, 7, or 8-level tape at 100 char/sec.
Printers	B 320	Line Printer	Prints 475 lpm; 120 print positions.
	B 321	Line Printer	Prints 700 lpm; 120 print positions.
	B 325	Line Printer	Prints 700 lpm; 132 print positions.
	B 328	Line Printer	Prints 1,040 lpm; 120 print positions.
	B 329	Line Printer	Prints 1,040 lpm; 132 print positions.
Magnetic Tape Units	B 422	Magnetic Tape Unit	Transfers data at 24 or 66KC.
	B 423	Magnetic Tape Unit	Transfers data at 24KC.
	B 424	Magnetic Tape Unit	Transfers data at 66KC.
	B 425	Magnetic Tape Unit	Transfers data at 18, 50, or 72KC.
Data Communications Devices	B 5480	Data Communications Control Unit	Transfers data between Processor and Terminal Units at 30KC.
	B 481	Teletype Terminal Unit	Controls up to 399 remote Teletype stations.
	B 483	Typewriter Terminal Unit	Controls up to 8 typewriter inquiry stations.
	B 484	Dial TWX Terminal Unit	Controls up to 8 Dial TWX stations.
	B 487	Data Transmission Terminal Unit	Provides buffering and interfacing for wide variety of remote devices.

.4 INPUT-OUTPUT EQUIPMENT (Contd.)

control up to 8 typewriter inquiry stations; and the B 484 Dial TWX Terminal regulates the use of up to 8 stations of the Dial TWX network. The B 487 Data Transmission Terminal Unit, unlike the other Burroughs terminal units, is general in purpose, permitting a B 5500 system to communicate with a varied mix of data transmission devices without the use of additional terminal units. Most remote devices that can use the low-speed and voice-grade lines of the telephone companies can be connected to a B 487, and ultimately to a B 5500, via Burroughs line adapters. All four models of Burroughs' terminal units are buffered and can simultaneously accept inquiries from as many remote devices as their individual buffer sizes will accommodate. Buffer sizes are specified at the time of manufacture.

.5 SOFTWARE

.51 Compilers

Users of the B 5500 Information Processing System normally do all of their programming in the ALGOL, COBOL, or FORTRAN languages. Two additional languages, OSIL and ESPOL, are available for special-purpose programming. OSIL, or Operating Systems Implementation Language, is a symbolic assembly language that was developed for writing Burroughs' Drum Master Control Program. ESPOL, or Executive System Problem Oriented Language, is a modified version of the ALGOL language that was designed to facilitate the writing of the Disk File Master Control Program.

Extended ALGOL for the B 5500 includes virtually all of the facilities of ALGOL 60 and a number of useful machine-dependent extensions that enable the programmer to take advantage of the hardware capabilities of the B 5500. Some of these extensions include device-oriented input-output constructs, partial-word and double-precision arithmetic operations, B 5500 Character Mode statements, and constructs to control the operations of Burroughs data communications terminal units. The ALGOL compiler delivers translation speeds that range between 600 and 800 source-program cards per minute, or up

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.51 Compilers (Contd.)

to 2500 magnetic tape card images per minute. More than 100 standard mathematical functions are included in the ALGOL library of subroutines.

COBOL-61 Extended for the B 5500 is a comprehensive version of the Department of Defense's COBOL-61 Extended language. All of Required COBOL-61 has been implemented, as well as most of the Elective features of COBOL-61. Two of the three principal extensions of COBOL-61 Extended — the SORT verb and the Mass Storage language facilities — have also been implemented. (Tape or Disk File sorting on the B 5500 system, using Burroughs-supplied software, is possible only through the use of the COBOL SORT verb and the Sort Generator within the COBOL compiler.) The Mass Storage facilities provide the programmer with direct control over both sequential and random processing of records on the Disk File. COBOL language facilities are also provided to permit the effective use of Burroughs' various types of data communications terminal units. Translation speeds of up to 800 source-program cards per minute have been achieved with the COBOL compiler, and the practicality of programming and debugging exclusively in COBOL has been effectively demonstrated through more than two years of successful user experience.

FORTRAN IV for the B 5500 includes virtually all of the language features proposed by the X.3.4.3 FORTRAN group of the American Standards Association. In comparison to this standard, B 5500 FORTRAN lacks only the provisions to handle double-precision and complex variable items. Burroughs has designed its FORTRAN language to duplicate, wherever possible, the facilities of the IBM 7090/7094 FORTRAN IV language in order to facilitate conversions of scientific and engineering installations to the B 5500. Burroughs' FORTRAN translator (called FORGOL 4) converts FORTRAN IV source statements into Extended ALGOL for eventual compilation by the ALGOL compiler. No FORTRAN language facilities have been implemented to date by Burroughs to provide direct control of Disk File storage or remote terminal devices.

Almost all program debugging on the B 5500 system is done at the source language level. MONITOR and DUMP statements are provided in the ALGOL and COBOL languages to produce tracers, dumps, and snapshots as requested by the programmer.

.52 Master Control Program (MCP)

The Master Control Program, or MCP, is a comprehensive operating system that controls the scheduling, loading, and execution of every program that is run on a B 5500 system. By means of close integration with the hardware interrupt facilities of the B 5500 system, the MCP controls multiprogramming, or the simultaneous processing of two or more independent program segments.

To use multiprogramming effectively with the B 5500 system, the only prerequisites are that the programs be written in small, logical segments, and that sufficient input-output equipment be available to service the needs of the multiple program segments. The MCP continually analyzes the list of scheduled jobs and decides, on its own, when and to what degree multiprogramming is possible. The sole criterion used by the MCP in making this decision is the continuous use of as many as possible of the processing and input-output facilities of the B 5500 system.

Other functions performed by the MCP include automatic handling of most error conditions, monitoring and control of communications between the system and the operator, complete logging of processing and input-output times for each program processed, and maintenance of the system and problem program libraries.

Two versions of the Master Control Program are offered for use with the B 5500 system: the Drum MCP and the more recent Disk File MCP, both designated according to the system device on which the MCP and its control routines reside. The Drum MCP is slightly less flexible than the Disk MCP in that the Drum MCP lacks the facilities to control Disk File and data communications operations. In addition, the Drum MCP gathers its scheduled programs on a Program Collection Tape and scans this tape to access programs that are appropriate for inclusion in a multiprogramming mix at any given time. By contrast, the Disk File MCP has direct access to any object program stored in the on-line program library. This advantage can lead to significant improvements in multiprogramming performance under control of the Disk File MCP. It should be noted that the storage of frequently-accessed program segments on the magnetic drum will be advantageous even when the Disk File MCP is used, due to the drum's faster average access time of 8.3 milliseconds.

Both versions of the MCP require the permanent use of the first 1,600 words of core storage for basic control routines; other portions of the MCP are called into core storage from drum or disc storage as required. Burroughs estimates that the MCP's control functions consume between 2 and 10 per cent of the system's total processing time in typical applications; yet the improvements in throughput gained by means of MCP-controlled multiprogramming can far overshadow the small MCP overhead time.



DATA STRUCTURE

.1 STORAGE LOCATIONS

<u>Name of Location</u>	<u>Size</u>	<u>Purpose or Use</u>
Word:	48 data bits plus 1 parity bit.	basic addressable unit; holds a data item, 8 characters, or 4 syllables.
Row:	6 data bits plus 1 parity bit.	magnetic tape; holds 1 character or 1/8 of a binary word.
Line:	120 or 132 characters	Line Printer reports.
Column:	12 positions	punched cards.
Block:	1 to N characters	magnetic tape, and Disk File in alpha-numeric mode.
Block:	1 to 1,023 words	magnetic tape and Disk File in binary mode.

.2 DATA FORMATS

<u>Type of Information</u>	<u>Representation</u>
Instruction	four 12-bit "syllables" per word; each can be an operator, literal, operand call, or descriptor call.
Descriptor	1 word; used for indirect addressing and supplementary control.
Integer number	1 word: 39 data bits + sign.
Floating-point number	1 word: 39 bits + sign for integer part, 6 bits + sign for exponent.
Character	6 bits (internal), 1 row (tape), or 1 column (cards).
Card image	4 card columns per word; 20 consecutive words per card.



PRICE DATA

CLASS	IDENTITY OF UNIT		PRICES			
	No.	Name	One-Time Charge*	Monthly Rental \$	Monthly Maintenance** \$	Purchase \$
PROCESSING AND CONTROL UNITS	B 5280	Central Processor System, including: B 5220 Central Control B 5281 Processor B 5282 I/O Subsystem (without I/O Channels) B 5290 Display and Distribution B 5310 Console B 5370 Power Supply		7,400	265.00	307,100
	B 5281	Central Processor (an optional second Processor)		4,500	120.00	186,750
	B 5283	I/O Channel (maximum of 4)		1,250	65.00	51,875
MAIN AND AUXILIARY STORAGE	B 460	Memory Module (6 μ sec core, 4,096 words)		1,250	55.00	51,875
	B 461	Memory Module (4 μ sec core, 4,096 words)		1,450	60.00	60,175
	B 430	Magnetic Storage Drum (32,768 words)		1,700	65.00	70,550
	B 5470	Disk File Control		590	65.00	26,550
	B 450	Basic Disk File/Data Communications Cabinet		255	40.00	11,475
	B 451	Disk File Expanded Control		200	25.00	9,000
	B 452	Basic Disk File/Data Transmission Terminal Unit Cabinet		255	40.00	11,475
	B 471	Disk File Electronics Unit		710	80.00	31,950
	B 475	Disk File Storage Module (9.6 million char)		990	115.00	44,550
INPUT-OUTPUT		<u>Readers, Punches, Printers</u>				
	B 122	Card Reader (200 cpm)		220	40.00	9,900
	B 123	Card Reader (475 cpm)		320	70.00	18,000
	B 124	Card Reader (800 cpm)		400	75.00	18,000
	B 129	Card Reader (1,400 cpm)		600	115.00	27,000
	B 303	Card Punch (100 cpm)		450	65.00	20,250
	B 304	Card Punch (300 cpm)		650	115.00	29,250
	B 141	Paper Tape Reader (500-1,000 char/sec)		400	70.00	18,000
	920	Input Code Translator		180	10.00	8,100
	B 341	Paper Tape Punch		190	40.00	8,550
	930	Output Code Translator		170	10.00	7,650
	B 320	Line Printer (475 lpm; 120 pos.)		810	170.00	54,000
	B 321	Line Printer (700 lpm; 120 pos.)		1,200	175.00	54,000
	B 325	Line Printer (700 lpm; 132 pos.)		1,275	185.00	57,375
	B 328	Line Printer (1,040 lpm; 120 pos.)		1,325	195.00	59,600
	B 329	Line Printer (1,040 lpm; 132 pos.)		1,400	205.00	63,000
	871	132 Print Position Capability, per I/O Channel	\$105.00	100	20.00	4,000

* One-time charge is applicable when certain features are added to an existing installation.

** Maintenance charges are slightly higher in rural areas.

CLASS	IDENTITY OF UNIT		PRICES			
	No.	Name	One-Time Charge*	Monthly Rental \$	Monthly Maintenance** \$	Purchase \$
INPUT-OUTPUT (Continued)		<u>Magnetic Tape Units</u>				
	B 422	Magnetic Tape Unit (24/66 KC at 120 ips)		800	155.00	36,000
	B 423	Magnetic Tape Unit (24 KC at 120 ips)		495	145.00	31,500
	B 424	Magnetic Tape Unit (66 KC at 83 ips)		850	165.00	38,250
	B 425	Magnetic Tape Unit (18/50/72 KC at 90 ips)		850	165.00	38,250
	872	Extended Magnetic Tape Capability, per I/O Channel (provides three-transfer-rate capability, beginning of tape, end of tape, and blank tape sensing)	\$500.00	100	20.00	4,500
		<u>Data Communications Devices</u>				
	B 5480	Data Communications Control		460	55.00	20,700
	B 249	Data Transmission Control Unit		295	45.00	13,275
	B 481	Teletype Terminal Unit:				
		120-Character Buffer		460	55.00	20,700
		240-Character Buffer		480	55.00	21,600
	B 483	Typewriter Terminal Unit		660	75.00	29,700
	B 493	Typewriter Inquiry Station		55	10.00	2,475
	B 484	Dial TWX Terminal Unit		700	80.00	31,500
	B 487	Data Transmission Terminal Unit		495	95.00	22,275
	873	B 487 Capability, per I/O Channel	\$50.00	100	20.00	4,500
	980	Dial TWX/Typewriter Adapter	\$50.00	40	5.00	1,800
	981	Teletype Adapter	\$50.00	60	10.00	2,700
	982	Dataspeed Type 2 Adapter	\$50.00	45	10.00	2,025
	983	801A Auxiliary Data Set Adapter	\$50.00	35	5.00	1,575
	984	UNIVAC 1004 Adapter	\$50.00	170	30.00	7,650
	985	IBM 1050 Adapter	\$50.00	85	15.00	3,825

* One-time charge is applicable when certain features are added to an existing installation.

** Maintenance charges are slightly higher in rural areas.

CONTROL DATA 6000 SERIES
INTRODUCTION

INTRODUCTION

. 1 SUMMARY

The Control Data 6000 Series is a group of three very fast, large-scale computer systems that have been designed to provide users with vast computational power in service of a large number of concurrently-operating programs. The marketing campaign for the 6000 Series, directed to both scientific and commercial computer users, emphasizes that the use of a large central computer system can be more economical for a company than the use of multiple smaller-scale systems scattered over a wide area.

Such operational goals have necessitated the design of specialized central computing equipment, flexible peripheral systems, extensive data communications facilities, and highly sophisticated software support. The minimum hardware configuration for the 6400 computer system — at the low end of the 6000 Series — includes one Central Processor with a 100-nanosecond clock-cycle time, a 1-microsecond Central Memory of 32,768 60-bit words, ten independently-operating Peripheral and Control Processors with private core storage units of 4,096 12-bit words each, and twelve floating input-output Data Channels that are each capable of transmitting I/O data at a rate of 2 million characters per second. Peripheral devices can include additional Peripheral and Control Processors, a new Extended Core Storage unit, several new display units, disc files, magnetic tape units, and all of the peripheral units designed for use with the Control Data 3000 Series systems. Control Data also makes available the controllers, multiplexors, and adapters necessary to control data communications networks that utilize a wide variety of remote terminal equipment.

Software for the 6000 Series represents a determined effort by Control Data to dispel a once-widespread impression that the corporation was unwilling or unable to develop and supply full-scale, integrated software support. Effective utilization of the powerful 6000 Series hardware demands a comprehensive, integrated software control system, and Control Data supplies such an operating system (SIPROS) with each 6000 Series system. The concurrent operation of multiple processors simultaneously executing a large number of programs is the normal mode of operation for the 6000 Series systems. Standard equipment configurations that include the Extended Core Storage unit are also well suited for time-sharing operations. The SIPROS operating system coordinates and controls the many levels of concurrent operations inherent in these multiprocessing, multiprogramming, and time-sharing modes of operation.

Monthly rentals for the 6000 Series systems range from about \$30,000 for a basic 6400 system to about \$170,000 for a large 6800 system. The 6800 computer system appears to be rivalled only by the recently-announced Burroughs B 8500 in competition for the title of "largest computer in the world," both in terms of magnitude of pure processing power and potential size of system hardware configuration.

The Control Data 6600 was first delivered early in 1965. The less powerful, cheaper Control Data 6400 system, announced in December 1964, will have its initial delivery early in 1966. The ultra-high-speed 6800 (more than four times faster than the 6600) was also announced in December 1964. First delivery of the 6800 system is expected sometime in 1967.

. 2 PROCESSORS. 2.1 Central Processors

Every Control Data 6000 Series computer system includes a Central Processor, a central core memory, and ten Peripheral Processors, each with a private core memory bank. The 6600 and 6800 Central Processors contain ten specialized, independently-operating functional units that theoretically enable them to execute up to ten machine instructions simultaneously. The 6400 Central Processor contains a single general-purpose instruction execution unit. Additional central processing power can be obtained in 6400 computer systems by including a second 6400 Central Processor in the configuration.

A 6000 Series Central Processor, at any one time, can access only one continuous segment of the central core memory, as defined by a Lower Boundary and an Upper Boundary. Any reference to a location outside this area which is attempted by a Central Processor program automatically results in an interrupt and a call to the executive program. The processor

.21 Central Processors (Contd.)

does not access the central memory directly either for instructions or operands; instead, it uses an eight-word instruction stack (which holds the present instruction and the previous seven instruction words) and 24 operating registers: eight A (Address) registers, eight B (B-line or index) registers and eight X (60-bit operand) registers. Although the B-registers are used for purposes analogous to index registers, the form of the 6000 Series instruction, which never directly refers to central core memory operands, precludes the use of indexing or indirect addressing in the usual sense of these terms.

The relationships among the processors, memory units, and input-output channels are shown in Figure 1. On the left, the input-output channels are all shown connected to a ten-way switch, so that input-output data can be passed through the independent memory banks of any of the ten identical Peripheral Processors (numbered 1 through 10). Each of the Peripheral Processors also has access to the central core memory of the system, and data can be transferred between the Peripheral Processor memories and the central memory without any Central Processor operations.

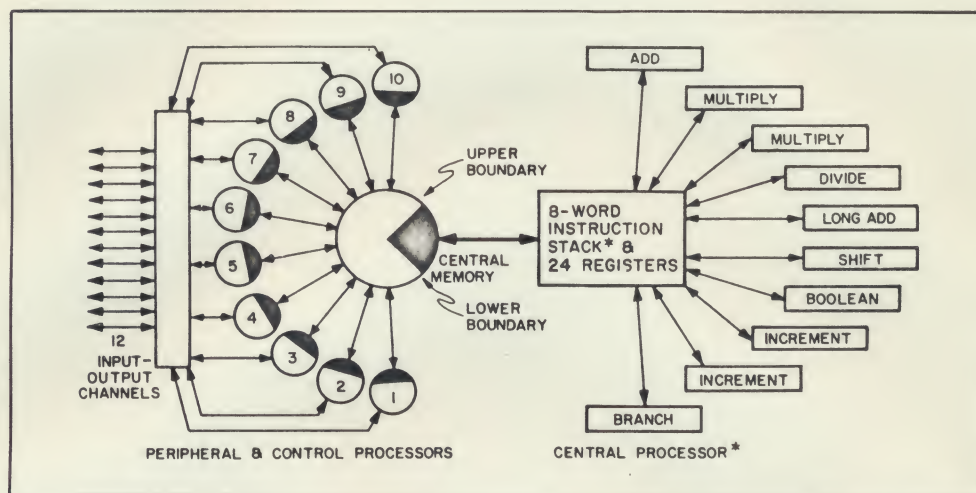


Figure 1. Structure of the Control Data 6000 Series Processors

* Note: The 6400 has no instruction stack nor multiple arithmetic processing units.

The instruction stack and the 24 operating registers act as a buffer between the comparatively slow core memory and the ten fast functional units, and allow the simultaneous operation of more than one of these units. Use of this relatively small number of registers permits great reductions in the instruction sizes, so that many three-address instructions require only 15 bits, or one-fourth of an instruction word.

Parallelism of operation is one of the keys to the rapid processing speeds of the 6000 Series Central Processors. In addition to the ten concurrently-operating functional units in the 6400 and 6600 Central Processors, all Central Processors in the Series have the ability to access simultaneously up to eight locations in Central Memory. As a result, instructions and operands can be accessed in anticipation of their actual need, and Central Processor delays caused by the need to await completion of Central Memory accesses can be greatly reduced.

The internal clock-cycle time of the 6400 and 6600 Central Processors is identical — 100 nanoseconds. Many instructions within the simplified 6000 Series instruction set consume only three or four internal Central Processor cycles. The 6600's 8-word instruction stack and 10 functional units make its performance considerably better than that of the 6400 (see comparative task timings in Table I). The 6800 Central Processor has a basic clock-cycle time of 25 nanoseconds and generally performs four times as fast as the 6600. However, Control Data intimates that the actual performance of the 6800 Central Processor will be significantly better than its specifications.

Table I lists some characteristics and representative execution times of the Control Data 6400, 6600, and 6800 Central Processors.

(Contd.)

TABLE I: CHARACTERISTICS OF THE 6000 SERIES CENTRAL PROCESSORS

System Identity			CONTROL DATA 6400	CONTROL DATA 6600	CONTROL DATA 6800
Computer System Report No.			263	264	265
DATA STRUCTURE	Word Length	Binary Bits	60	60	60
		Decimal Digits	18	18	18
		Characters	10	10	10
	Floating Point Representation	Radix	Binary	Binary	Binary
		Fraction Size	48 or 96 bits	48 or 96 bits	48 or 96 bits
		Exponent Size	11 bits plus sign	11 bits plus sign	11 bits plus sign
CENTRAL PROCESSOR	Model Number		6401, 6404, 6405	6601, 6604, 6605	6801, 6804, 6805
	Arithmetic Radix		Binary	Binary	Binary
	Operand Length, Words		1	1	1
	Instruction Length, Words		1/4 or 1/2	1/4 or 1/2	1/4 or 1/2
	Addresses per Instruction		3	3	3
	Likely Fixed Point Execution Times, μ sec (5 Digits Min. Precision)	$c = a + b$	0.6*	0.3*	0.08*
		$c = ab$	—	—	—
		$c = a/b$	—	—	—
	Likely Floating Point Execution Times, μ sec	$c = a + b$	1.1*	0.4*	0.1*
		$c = ab$	5.7*	1.0*	0.25*
		$c = a/b$	5.6*	2.9*	0.73*
	Checking	Data Transfers	None	None	None
		Arithmetic	Interrupt	Interrupt	Interrupt
	Number of Index Registers		Eight	Eight	Eight
	Indirect Addressing		Not applicable	Not applicable	Not applicable
	Special Editing Capabilities	Mathematical	None	None	None
		Commercial	None	None	None
	Boolean Operations		AND, INC OR, EXC OR	AND, INC OR, EXC OR	AND, INC OR, EXC OR
	Table Look-up		None	None	None
	Console Typewriter	Input	Yes	Yes	Yes
		Output	No; displays are used	No; displays are used	No; displays are used
	Features and Comments		Supported by 10 Peripheral Processors; sequential execution of one instruction at a time.	Supported by 10 Peripheral Processors; up to 10 instructions can be executed concurrently.	Four times as fast as the CDC 6600; otherwise almost identical.

* Execution times are elapsed times for Register-to-Register tasks, with no allowance for transferring data to and from main core storage; these data transfers can be overlapped and do not necessarily add to the time used.

22 Peripheral and Control Processors

The ten Peripheral and Control Processors that form an integral part of every Control Data 6000 Series computer system are logically and functionally independent processors, each with a private core storage bank of 4,096 12-bit words. The Peripheral Processors have an instruction repertoire of 64 instructions, including fixed-point binary addition and subtraction, testing instructions, incrementing instructions, and an Exchange Jump instruction that facilitates switching between programs.

Due to the power and flexibility of the Peripheral Processors, many tasks that are performed by the central processors in more conventional systems are divided among the 6000 Series Peripheral Processors, permitting the 6000 Series Central Processor to concentrate upon performing the central computational loops of multiple programs. The principal roles of the Peripheral and Control Processors include controlling all input-output operations, performing executive and monitor services for the entire system, performing data transcription operations, and serving the Central Processor program by performing time-consuming operations such as data conversions, file searching, and array manipulations.

The Peripheral and Control Processors that are used with the Control Data 6400 and 6600 systems have a clock-cycle time of 1 microsecond and use core storage modules with the same cycle time. The 6800 Peripheral Processors have an internal clock-cycle time of

.22 Peripheral and Control Processors (Contd.)

250 nanoseconds and a matching cycle time in their core memory modules. Most Peripheral Processor instructions can be executed within one to four processor cycles. Transfer of data between each of the Peripheral Processors and any of the twelve standard input-output Data Channels can proceed at up to 2 million characters per second in the 6400 and 6600 computer systems and at up to 8 million characters per second in the 6800 computer system.

.3 INTERNAL STORAGE

The Control Data 6000 Series offers a wide variety of internal storage devices of diverse capacities and speeds, designed to serve specific functions within the total integrated computer system. Central Memory can be considered as the private, high-speed core storage for the Central Processor, with direct data paths to the Peripheral Processors and to the optional Extended Core Storage unit. Central Memory capacities range from 320,768 to 1,310,720 six-bit characters; transfer rates extend from 80 to 400 million characters per second, depending on the unit's size and model. Table II lists the principal characteristics of the Central Memory units.

TABLE II: CENTRAL MEMORY CHARACTERISTICS

Computer System	6400 or 6600			6800		
Core Storage Capacities, in 60-bit Words	32,768	65,536	131,072	32,768	65,536	131,072
Cycle Time per Word, μ sec	1.0	1.0	1.0	0.25	0.25	0.25
Independent Banks of Storage	8	16	32	8	16	32
Interleaved Cycle Time per Word, μ sec	0.13	0.10	0.10	0.03	0.025	0.025
Peak Transfer Rate, Millions of Words per Second	8	10	10	32	40	40

Each of the ten Peripheral Processors has a core memory unit consisting of 4,096 12-bit words to serve the general computational needs of the Peripheral Processor, to hold in residence the system's control programs, and to provide private input-output buffer areas for data transferred to and from Central Memory. Data can be transferred between a Peripheral Processor memory unit and Central Memory at the rate of 2 million and 8 million characters per second in the 6400/6600 and 6800 systems, respectively.

Control Data 6000 Series users can optionally include the newly-developed Extended Core Storage unit in their hardware configuration to provide very fast and comparatively inexpensive auxiliary core storage in capacities up to 167 million characters (see Table III). Blocks of data can be transferred between Extended Core Storage and Central Memory at the rate of 100 million characters per second in the 6400 and 6600 systems. Similar transfers in the 6800 can be effected at the rate of 400 million characters per second. The entire 1,310,720 characters of a 131K 6800 Central Memory can be exchanged with the same number of characters stored in Extended Core Storage in 6.5 milliseconds. These data transfer

TABLE III: EXTENDED CORE STORAGE CHARACTERISTICS

Computer System	6400 or 6600				6800	
Extended Core Storage Capacities, in 60-Bit Words*	131,072	262,144	1,048,576	2,097,152	524,288	1,048,576
Number of Memory Banks	1	2	8	16	4	8
Number of Characters Accessed per Cycle	80	80	80	80	160	160
Cycle Time, in Microseconds	3.2	3.2	3.2	3.2	1.6	1.6
Peak Transfer Rate, Millions of Characters per Second	25	50	100	100	400	400

* Larger Extended Core Storage capacities, ranging up to 16,777,216 60-bit words, are available upon request.



(Contd.)

.3 INTERNAL STORAGE (Contd.)

rates are so impressive that Control Data plans to utilize the technique of swapping programs between Extended Core Storage and Central Memory as the heart of its time-sharing systems for the 6000 Series. This "roll-in/roll-out" method provides the Central Processor with almost immediate access to any program.

No internal parity checking is performed in any of the 6000 Series core storage units. Control Data emphasizes the high degree of reliability built into its third-generation core memories and suggests the use of software checking techniques when absolute assurance of reliability is required. The extra time required to perform some form of software checking is implied as being insignificant in view of the extremely high processing speeds of the 6000 Series systems.

Three types of random-access disc storage units are offered as part of the 6000 Series hierarchy of storage devices. The 6603 Disk File is a Bryant-made unit capable of storing up to 80.8 million characters. Either the 6603 Disk File or the new 6607 or 6608 Disk File (with a better price/performance ratio) must be included in every 6000 Series configuration as the "System Disk." The 6607 can store up to 84 million characters of data, and the 6608 can hold up to 168 million characters. These two devices feature rapid-access actuator arms in a reactively-balanced positioning mechanism developed by Control Data. The new 850 Series Disk Storage Drives can also be used with the 6000 Series. These units provide inexpensive "Disk Pack" storage with capacities up to 9.6 million characters per pack, and Model 852's Disk Packs are compatible with those used by the IBM 1311 Disk Storage Drive. Table IV lists the principal features of these random-access disc storage devices.

TABLE IV: DISC STORAGE CHARACTERISTICS

Device	Capacity (millions of characters per unit)	Average Access Time (milliseconds)	Data Transfer Rate (char/sec)	Report Reference
6603 Disk File	80.8	93	1,048,000 to 1,342,000	260:044
6607 Disk File System	84	59.3	1,680,000	260:045
6608 Disk File System	168	59.3	3,360,000	260:045
852 Disk Storage Drive	2.0 to 2.9	77.5	77,730	260:046
853 Disk Storage Drive	4.8	70	208,333	260:046
854 Disk Storage Drive	9.7	70	208,333	260:046

INPUT-OUTPUT EQUIPMENT

Control Data provides a wide range of local and remote peripheral devices for the 6000 Series, emphasizing that input-output equipment considerations should not be permitted to impede the performance of the powerful 6000 Series processing and core storage units. Any of the input-output units provided for the Control 3000 Series computer systems (and described in Report Sections 245:041 through 245:102) can be connected to a 6000 Series system through use of 6681 Data Channel Converters. Several other devices have been developed especially for use with the 6000 Series; these units are described below.

- 6411 Augmented Input-Output Buffer and Control — a large-scale multiple-device subsystem that can virtually double the input-output capabilities of a basic 6000 Series configuration. The 6411's components include 12 high-speed bidirectional Data Channels, 10 Peripheral and Control Processors, each with a private core storage unit that consists of 4,096 12-bit words, and one Main Memory unit consisting of 16,384 60-bit words. The 6411 is, in effect, an additional 6000 Series computer system, minus the Central Processor. Up to twelve Augmented Input-Output Buffer and Control Units can be connected to a 6400 or 6600 computer system.
- 6602 Display Console — a dual-display cathode-ray unit used as the basic local console device in every 6000 Series computer system. The 6602 uses two 10-inch cathode-ray tubes as the sole output media and uses a console typewriter for input purposes. There are no other displays, indicators, switches, or other special-purpose hardware devices on the console. The system can edit and display instructions to the operator, messages and/or graphs for the programmer, or any other relevant data, in any appropriate format. The display can be retained on the scope as long as desired (perhaps until some action such

.4 INPUT-OUTPUT EQUIPMENT (Contd.)

as mounting a tape has occurred) and then erased to make room for other displays. Each line in the display can be up to 64 characters wide, and a maximum of 32 lines can be displayed. Graphical data can be displayed, but at present there is no provision for light pen input.

During normal operation, one of the two scopes is reserved for communication with the computer operators and the other is used for messages and displays initiated by the program itself (see Figure 2). At least one Model 6602 Display Console is used with each Control Data 6000 Series system. Additional consoles can be used in conjunction with time-shared operations, with each scope servicing a different program or group of programs.

- 6090 Entry/Display Console — a 14-inch cathode-ray tube display device and associated typewriter-style keyboard, used as the basic component of a high-speed data entry and retrieval system. Slow-speed card reader and printer units can operate in conjunction with the 6090 Console to provide hard-copy records of the data requests and the retrieved information. Either 10 or 20 lines of 50 symbols can be displayed on the 6090's output screen. The 6090 is usually used as a remote unit, communicating with the central computer over voice-grade telephone lines.
- 6060 Remote Calculator — a desk-type electronic calculator that permits users in remote locations to utilize the mathematical processing capabilities of a large-scale central computer. Problems can be keyed in on the keyboard, using a simplified FORTRAN-like mathematical notation. Computer-generated solutions are transmitted to the site of the 6060 Calculator over voice-grade lines and displayed on an illuminated 12-digit display panel.
- 626 14-Track Magnetic Tape Unit — a specially-designed unit capable of recording at 800 rows per inch, with each row holding two 6-bit characters and two parity bits. The speed of the one-inch tape is 150 inches per second, developing a peak data transfer rate of 240,000 6-bit characters per second. The 626 is not an industry-compatible unit; it was designed to provide high-performance data transfer capabilities within a 6000 Series system. (Standard 7-track and 9-track IBM-compatible magnetic tape units are also provided for use with the 6000 Series.)

.5 DATA COMMUNICATIONS

Due to the great power inherent in the 6000 Series processing equipment, many installations will include numerous remote devices communicating with the central computer via communications lines. Control Data offers facilities to connect any of its own remote terminal equipment and most of the industry-standard terminal devices to the 6000 Series systems.

The 3276 Communication Terminal Controller is a multiplexing control unit that enables a wide variety of standard and specialized data communications devices to be connected to the standard 6000 Series Data Channels via a 6681 Data Channel Converter. First used with the Control Data 3000 Series systems, the 3276 Controller can control up to 32 simplex telegraph-grade lines (16 sending and 16 receiving), or up to 16 half-duplex or full-duplex telegraph-grade lines, or up to 8 half-duplex or full-duplex voice-grade lines. The 3276 provides the speed and mode conversions required to communicate with the 6000 Series systems.

The 6600 Series Data Set Controllers are single-speed communications control units designed specifically for the 6000 Series computer systems. Five different models permit various types of communications devices and remote computer systems to be connected directly to the 6000 Series Data Channels. The 6600 Series Controllers communicate with the remote devices over the public or private communications facilities of the telephone or telegraph companies, using standard data set modems as interfacing units at the remote and central ends of the transmission lines. One model permits computer-to-computer communication at 40,800 bits per second over Telpak A lines. Another model permits up to 200 Teletype Model 33 or 35 terminals to communicate with a single 6000 Series Data Channel.

.6 SOFTWARE

Five of the first six users of the Control Data 6600 were supplied with an interim software package centered around the "Chippewa" operating system. In addition to the standard operating system functions, such as system monitor, loader, peripheral and display device control, and library supervision, the Chippewa package also provides a FORTRAN IV compiler and a Central Processor assembly language. According to several reports, the performance of the Chippewa operating system and its components has been unimpressive and has failed to harness the potential power of the 6000 Series hardware. Control Data emphasizes that the Chippewa system is simply an interim software package, designed to permit early users to begin productive processing as soon as possible.

(Contd.)



.6 SOFTWARE (Contd.)

Beginning in December 1965 and continuing through 1967, the SIPROS operating system and its associated control routines and compilers will be delivered. SIPROS (Simultaneous Processing Operating System) is the official operating system for the 6000 Series. Control Data expects that overall efficiency of the SIPROS programs will be at least 50% better than that of the original Chippewa operating system.

SIPROS will be delivered in three phases, with each phase adding new or expanded language and control modules. SIPROS 1.0, to be delivered in December 1965, includes basic operating system functions, many of which are listed below. Phase 2 will be delivered in January 1966 and includes the routines necessary to handle all 3000 Series peripheral device controllers. SIPROS 3.0, scheduled for delivery in April 1966, will include all announced SIPROS functions in versions that will operate with any validly-configured 6000 Series system. A specialized version of SIPROS designed for remote time-sharing operations and centering around the Extended Core Storage unit is expected to be delivered during the third quarter of 1967.

SIPROS' Executive and Monitor routines assume full control of the system and multiprocess jobs from a job stack, using priorities to decide schedule details. One of the functions is to place the output data from a program in temporary storage when this is necessary to allow the program to run at peak operational speed. Later, when appropriate equipment becomes available, the operating system handles the output data transcriptions runs.

The operating system handles the compilation and the execution of programs written in FORTRAN-66, COBOL, ALGOL, ASCENT (the Central Processor assembly language), and ASPER (the Peripheral Processor assembly language). It is common practice for a programmer to write a program in more than one language, intermingling FORTRAN statements with ASCENT and ASPER coding, but using a common symbol table. During compilation, the FORTRAN compiler and the assemblers are loaded into Central Memory as one program in order to save load time when switching from one language to another. The resulting object program, now in binary machine-language form, can be tested and executed as one of the programs in the job stack.

SIPROS requires the use of a Model 6603 or 6607/6608 Disk File, two magnetic tape units, a card reader, card punch, and printer. Two of the ten Peripheral Processors are permanently dedicated to the operating system, and others are used by the operating system whenever they are needed. Functions which are normally handled by the Peripheral Processors include disc reading and writing (which takes two processors), loading jobs into the system, bringing jobs from the disc unit into the central memory for execution, job termination functions, data transcription functions associated with jobs being executed, off-line data transcriptions, and comparisons. These services use the Peripheral Processors on an as-available basis. A programmer can "take over" one or more Peripheral Processors for his own program, but of course this will reduce the number of Peripheral Processors available in the pool.

Control cards loaded with each job describe time limits, equipment requirements, termination instructions for normal and error cases, etc. The time limits are specified in terms of central processor time usage, maximum number of cards punched, maximum number of lines printed, and maximum length of time the program should spend in a specific input-output loop. No provision is made for placing a maximum limit upon total elapsed time for each program; this is because several programs will normally be processed concurrently, and any one program may be delayed as a result of overriding priorities of other programs.

When an error stop occurs (due to an out-of-range address, exponent overflow, or occurrence of an indefinite result), a map and/or a dump of the job's allocated memory area is produced if previously requested. In any case, upon job termination a Job Accounting Log will be created for each program and either displayed on the console or written on some output medium. Charge distribution is a responsibility of the installation. A display of a typical job accounting record is shown in Figure 2.

During the execution of a job, an input-output delay or some other occurrence may prevent that job from making further immediate use of the Central Processor. In such a case the Executive routine that resides in a reserved Peripheral Processor is notified by the monitor routine, whereupon it activates one of the other programs which is resident in the central core memory. That program will continue to make use of the central processing facilities until it too is interlocked, or until some other program which has a higher priority is able to make use of the central processing facilities. Each changeover from program to program can be accomplished within five to ten microseconds through use of a special Exchange Jump instruction.

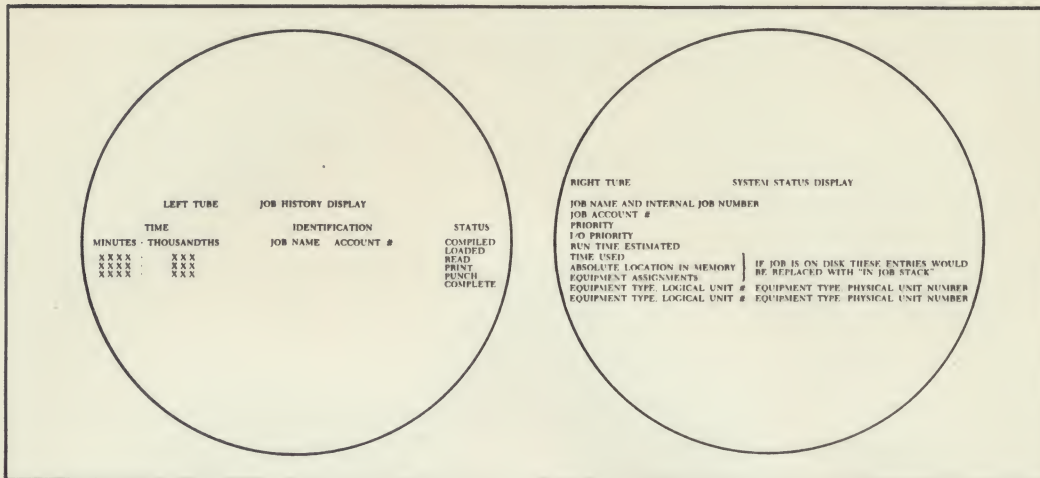


Figure 2. Cathode-Ray Display of a Set of Job Accounting Information as Produced for Each Job Handled by the SIPROS Operating System

.6 SOFTWARE (Contd.)

Control Data's FORTRAN-66 language is basically the same as FORTRAN-63 for the Control Data 1604-A computer system. The FORTRAN-66 dialect of FORTRAN IV permits the use of single and double precision floating-point, integer, complex, and logical operations in mixed mode. ENCODE/DECODE statements permit internal transfers of data within core memory, and other specific instructions are provided for input-output buffering purposes when the programmer elects to override the system's automatic buffering facilities. FORTRAN-66 also permits the use of 6000 Series central register names as operands and the use of ASPER and ASCENT assembly-language statements at any place in the FORTRAN program. The FORTRAN-66 compiler provides an optional code optimization algorithm which simulates the execution of the initially-generated object code in order to determine ways to utilize more effectively the Central Processor's 24 central registers and (in the 6600 and 6800 systems) 10 functional units.

Control Data also supplies an ASA standard FORTRAN IV compiler that can function under control of SIPROS and a special translation program that can convert existing FORTRAN IV programs to the more flexible (but non-compatible) FORTRAN-66 language.

The ASCENT and ASPER assemblers are parts of the basic integrated software package that also includes the FORTRAN-66 compiler and a library maintenance system (LIBRIOUS). ASCENT, the assembly language used for coding Central Processor routines, contains standard assembly-language features, including the use of literals, programmer-defined macros, pseudo-instructions, and system macros to control the use of Central Memory and disc storage areas. Macros are also provided to control program overlays, to initiate Peripheral Processor programs, and to communicate with SIPROS.

The ASPER assembly language permits direct control of the Peripheral Processors when specialized tasks are to be executed. (Normally, all Peripheral Processor task assignments and specifications are performed by SIPROS according to the needs of the currently-operating Central Processor program). ASPER includes all the facilities necessary to utilize the input-output functions of the Peripheral Processors, as well as the facilities to use these processors as standard computational/logical units. ASPER statements can be coded in-line with ASCENT statements.

SIPROS provides a control system called the File Manager for handling the storage, retrieval, usage, and modification of data files stored on mass storage devices. Routines are supplied for full control of drum, disc, and Extended Core Storage units, and for dumping and reloading magnetic tape files. The File Manager can normally perform its functions through the use of a single Peripheral Processor, using SIPROS control routines whenever possible.

A COBOL-65 compiler is promised for use with the 6000 Series, but no delivery date has yet been announced. The 6000 Series ALGOL compiler is scheduled for delivery in August, 1966. Other software packages planned for the 6000 Series include KWIC, SIMSCRIPT, PERT TIME, PERT COST, a Statistical Programming Package, an IBM 7090/7094 Simulator, a linear programming routine, and a sort/merge routine.


**CONTROL DATA 6000 SERIES
PRICE DATA**
PRICE DATA

CLASS	IDENTITY OF UNIT		PRICES		
	No.	Name	Monthly Rental \$	Monthly Maintenance \$	Purchase \$
CENTRAL PROCESSORS	6401	Central Computer for 6400 system, with 131,072 words of core storage, 10 Peripheral Processors with storage, power and cooling apparatus	50,000	6,100	2,100,000
	6404	Central Computer — same as 6401, but with 65,536 words of core storage	30,950	3,525	1,300,000
	6405	Central Computer — same as 6401, but with 32,768 words of core storage	17,850	2,340	750,000
	6410	Additional Central Processor, with arithmetic and control functions of the basic 6400 Central Processor	9,700	1,000	410,000
	6411	Augmented Input-Output Buffer and Control, with 16,384 words of core storage and 10 Peripheral Processors with storage	7,100	530	340,000
	6601	Central Computer for 6600 system, with 131,072 words of core storage, 10 Peripheral Processors with storage, power and cooling apparatus	71,500	7,210	5,110,000
	6604	Central Computer — same as 6601 but with 65,536 words of core storage	53,500	6,400	3,450,000
	6605	Central Computer — same as 6601, but with 32,768 words of core storage	41,900	5,700	2,600,000
	6801	Central Computer for 6800 system, with 131,072 words of core storage, 10 Peripheral Processors with storage, power and cooling apparatus	77,500	7,210	3,600,000
	6804	Central Computer — same as 6801, but with 65,536 words of core storage	53,500	6,400	2,400,000
	6805	Central Computer — same as 6801, but with 32,768 words of core storage	41,900	5,700	1,800,000

CLASS	IDENTITY OF UNIT		PRICES		
	No.	Name	Monthly Rental \$	Monthly Maintenance \$	Purchase \$
BULK CORE STORAGE	6830	Extended Core Storage; 524,288 words	29,000	1,800	800,000
	6831	Extended Core Storage; 1,048,576 words	58,000	2,800	1,600,000
INPUT- OUTPUT	6602	<u>Consoles and Displays</u> Console Display (with controller)	900	160	45,750
	6060	Remote Calculator	125	18	4,500
		<u>Disk File Storage</u>			
	852	Disk Storage Drive	?	?	?
	853	Disk Storage Drive	320	?	14,200
	854	Disk Storage Drive	470	?	21,000
	6603	Disk System	5,600	610	225,000
	6607	Disk System	4,900	610	200,000
	6608	Disk System	7,250	755	295,000
		<u>Magnetic Tape</u>			
	626	Magnetic Tape Transport; 240,000 characters/sec, 14 tracks.	1,075	185	51,600
	6622	Magnetic Tape Controller	560	85	24,000
		<u>Data Communications</u>			
	3276	Communication Terminal Controller	250	55	12,500
	6675-D	Data Set Controller	1,450	180	60,000
	6676	Data Set Controller	1,900	120	75,000
	6677-A	Multiplexor	1,250	110	50,000
	6677-B	Multiplexor	1,500	130	60,000
	6678	Data Set Controller	1,900	150	75,000
DATA CHANNEL CONVERTER	6681	Data Channel Converter	310	40	13,500
	6682	Satellite Coupler, for direct connection of 6000 Series Data Channels	90	12.50	4,100

NOTE: FOR PRICES OF THE CONTROL DATA 3000 SERIES PERIPHERAL UNITS,
SEE PAGE 245:221.101.



SUMMARY REPORT: CONTROL DATA 1604

.1 AVAILABILITY

The Control Data 1604 is a medium-to-large-scale data processing system that is primarily oriented toward scientific and engineering applications which require extensive computation and a fairly large amount of internal storage. The 1604 was Control Data's first general-purpose digital computer system. Introduced as a solid-state contender for the phase of the computer market that was then dominated by the IBM 704, the 1604 was initially delivered in January 1960, two months after the IBM 7090.

Manufacture of the 1604 was phased out during 1962, when it was superseded by an improved model designated the 1604-A. The 1604-A features a more powerful interrupt system and the ability to handle higher input-output data rates with lower central processor delays. These refinements are described in Section 243:011 of the CDC 1604-A report.

A total of approximately sixty 1604 and 1604-A systems were manufactured before production facilities were shifted over to Control Data's newer 3000 Series systems in 1964. Used 1604 and 1604-A systems can be purchased or rented from Control Data Corporation, and Control Data assures prospective users that it will continue to provide full hardware maintenance and software support services. No inventory of used 1604 systems is maintained; they are offered on an "as available" basis, and a turnaround time of about three months is required to refurbish each returned system.

.2 HARDWARE

A Control Data 1604 system can contain 8,192, 16,384, or 32,768 word locations of core storage. Each 48-bit word can hold a fixed-point or floating-point number, a binary data pattern, or two 24-bit instructions. The core storage is divided into two banks, each with independent access facilities and a 6.4-microsecond cycle time. The resulting capability to overlap core storage accesses leads to an effective cycle time of approximately 4.8 microseconds. No parity checking is performed on data transferred to or from core storage.

The 1604 Central Processor operates in the binary mode on 48-bit operands in either fixed-point or floating-point form. Floating-point data values are represented by an 11-bit exponent and a 36-bit-plus-sign fraction. A useful repertoire of arithmetic, logical, branching, storage search, and data transfer operations is provided, but there are no direct facilities for radix conversion, format control, or multi-word data transfers. Instructions are executed at the rate of about 50,000 per second in typical scientific applications.

Each instruction consists of 24 bits: a 6-bit operation code, a 3-bit index designator, and a 15-bit address portion. The index designator can specify either indexing, using one of six index registers, or indirect addressing, which may be recursive. The address portion can specify an operand address in core storage, a literal operand, or a shift count.

The fact that each 48-bit word holds a pair of instructions causes some programming complications which necessitate careful "housekeeping" when coding in assembly language. All transfers of control (jumps) must be to the first instruction of a pair, and certain instructions behave differently depending upon which half of a word they occupy.

An interrupt system permits interruption of the program when an input-output controller becomes ready, when an arithmetic overflow occurs, or when the real-time clock overflows. The programmer can specify which controllers and channels shall be allowed to generate interrupt signals; but when an interrupt occurs, programmed testing is required to identify the specific condition that caused it. The 1604's unsophisticated interrupt system and lack of facilities for inter-program protection make it unsuitable for multiprogrammed operation.

The 1604 contains three pairs of buffered data channels for conventional input-output operations. Each pair consists of one input channel and one output channel. Logically, up to eight controllers can be connected to each pair of channels, and some of the controllers can, in turn, accommodate up to eight I/O devices. Power supply considerations, however, impose lower practical limits on certain configuration combinations. A seventh data channel, which is unbuffered and requires continuous Central Processor control, is intended primarily for computer-to-computer communications.

. 2 HARDWARE (Contd.)

Up to three input and three output operations can occur simultaneously provided that none of them has a peak speed of over 30,000 characters per second. Each one-word data transfer between core storage and a peripheral device requires about 14.8 microseconds of Central Processor time, and the 1604's I/O control method imposes severe restrictions upon the number of high-speed I/O operations that can take place simultaneously. For example, two 62,500-character-per-second magnetic tape units can be serviced simultaneously only if no other I/O operation is attempted on any of the other channels while the two tape units are operating.

The principal peripheral devices used with Control Data 1604 systems are as follows:

- A 350-character-per-second paper tape reader and a 110-character-per-second paper tape punch, both of which are mounted in the 1604 console desk along with a console typewriter.
- 1607 Magnetic Tape Subsystem, consisting of a Synchronizer Control Unit and up to four Ampex tape units in a single cabinet. Peak speed is 30,000 characters per second, using IBM 729-compatible tape recorded at 200 rows per inch in either BCD or binary mode.
- 1609 Card Reader/Punch, a Control Data adaptation of the IBM 521 Punching Unit, which can read and/or punch up to 100 cards per minute.
- 1617 Card Reader, which reads 80-column cards column by column at 250 cards per minute.
- 1612 Line Printer, a Control Data adaptation of an Anelex Series 4-1000 printer rated at either 1,000 or (for improved print quality) 667 lines per minute.
- 1608 Control Unit, which controls up to eight IBM 729 II or 729 IV Magnetic Tape Units at data transfer rates of 15,000 to 62,500 characters per second.
- 1610-A Control Unit for one 100-cpm IBM.532 Card Punch and/or one IBM 88 Collator used as a card reader at 650 cpm (one feed) or 1,300 cpm (both feeds).

Controllers for other IBM card readers, punches, printers, and magnetic tape units were formerly offered for the 1604, and provisions can probably be made for connecting some of the more recent Control Data peripheral devices used in CDC 1604-A systems (Report 243:).

. 3 SOFTWARE

Although Control Data Corporation did not originally offer software support for its computers, it soon decided to do so, and for the past five years it has been seriously engaged in providing standard software. An impressive variety of programming systems, applications programs, and subroutines developed by both Control Data and 1604 users is now available. The software facilities that are properly documented and in general use are supplied through a well-organized, CDC-supported users' group called CO-OP.

Software facilities currently available for the 1604 and 1604-A include the CO-OP Monitor, the CODAP-1 Assembler, three FORTRAN compilers, a COBOL compiler, an ALGOL compiler, a JOVIAL compiler, a sort/merge routine, a PERT routine, a linear programming package, and many mathematical and scientific routines.

The CO-OP Monitor is an operating system that provides run-to-run supervision and conveniently integrates program translation, debugging, and execution functions. CODAP-1 is the basic symbolic assembly language for the 1604. The three versions of FORTRAN that have been implemented for the 1604 are FORTRAN-60, a compiler designed for the rapid compile-and-execute operation using a restricted version of the FORTRAN II language; FORTRAN-62, which compiles more efficient object programs and can incorporate independently-compiled subprograms; and FORTRAN-63, which offers most of the language facilities of FORTRAN IV.



PRICE DATA: CONTROL DATA 1604

The following prices are the list purchase, single-shift rental, and single-shift maintenance prices currently in effect for Control Data 1604 equipment. In general, they are the same as the prices that were in effect while the 1604 system was in production. It is likely that this equipment can now be obtained at lower prices.

CLASS	IDENTITY OF UNIT		PRICES		
	No.	Name	Monthly Rental \$	Monthly Maintenance \$	Purchase \$
CENTRAL PROCESSOR	1604	Central Processor with: 8,192 words of core storage	22,500	1,775	750,000
		16,384 words of core storage	25,000	1,970	830,000
		32,768 words of core storage	30,100	2,360	990,000
		Price includes console, paper tape reader and punch, typewriter, and motor/generator			
STORAGE		Included in Central Processor price			
INPUT-OUTPUT	1607	Magnetic Tape Subsystem (Synchronizer plus 4 tape units)	5,050	750	145,000
	1608	Control Unit for up to 8 IBM 729 II or 729 IV Magnetic Tape Units	2,050	100	70,000
	1609	Card Reader/Punch	1,175	190	47,000
	1610-A	Control Unit for IBM 523 Card Punch and/or IBM 88 Collator	1,500	180	57,000
	1612	Line Printer	1,840	400	73,500
	1617	Card Reader	580	155	22,500



SUMMARY REPORT: CONTROL DATA 160

.1 AVAILABILITY

The Control Data 160 is a desk-size, solid-state computer designed primarily for small-scale scientific applications. Because a 160 system can include magnetic tape units, line printers, and punched card equipment, it is also suitable for use with larger computers as an off-line data transcription system or as a directly-connected satellite computer.

Initial deliveries of Control Data 160 systems were made in May 1960. Deliveries of the Control Data 160-A, a more powerful and more expensive version of the 160, began in July 1961. The 160-A features larger core storage capacities and a buffered input-output channel; it is fully described in Computer System Report 244. Programs written for a 160 system can be executed on a similarly-equipped 160-A, but modifications will be required if the user wishes to take advantage of the 160-A's increased storage capacity and simultaneity. Programs written for a 160-A system cannot, in general, be executed on a 160 without modification.

A total of more than 400 Control Data 160 and 160-A computers were manufactured. Both the 160 and 160-A are no longer in production, but used systems can be purchased or rented from Control Data Corporation on an "as available" basis. Control Data assures prospective users that it will continue to provide full hardware maintenance and software support services.

Two other computer systems whose design is closely patterned after that of the 160 are currently being produced by Control Data. The 160-G, initially delivered in March 1964, offers larger and faster core storage (from 8K to 131K words with a 1.5-microsecond cycle time) and a larger word size (14 bits), but it can be operated in a compatibility mode that enables it to execute 160-A programs without alteration. The 8090 Control Computer uses a central processor that is program-compatible with the 160-A, but the 8090 is designed primarily for communications and control applications. The 8090 is the central component of several message-switching systems installed by Control Data.

.2 HARDWARE

The basic Control Data 160 system consists of the desk-size central processor, 4,096 twelve-bit words of core storage, and a built-in 350-character-per-second paper tape reader and 110-character-per-second paper tape punch. Core storage cycle time is 6.4 microseconds, and no expansion of the basic 4,096-word capacity is possible. (A 160-A system can have from 8,192 to 32,768 words.) No parity checking is performed on data transferred to or from core storage.

The short word length of 12 bits (11 data bits plus sign bit) provides a precision of only 3.3 decimal digits and leads to numerous programming complexities. Arithmetic of double, triple, or quadruple precision will need to be performed to obtain the precision required for many scientific applications. The single-address instructions are one or two words in length, and there are seven different addressing modes. In general, instructions that reference operands in core storage are two words long, but a single word can hold an instruction that references a location within 64 locations of the present setting of the instruction counter. Limited facilities are provided for indexing (using a single index register) and for indirect addressing (non-recursive).

The 160 has an instruction repertoire of 97 instructions, most of which are variations of a few basic instructions. The basic arithmetic mode is fixed-point binary on single-word operands. There are add-to-storage and Boolean instructions, but no standard facilities are provided for multiplication, division, direct comparisons, radix conversions, or floating-point arithmetic. In the basic 160 system, these functions are usually performed by standard subroutines. The optional 168-1 Auxiliary Arithmetic Unit provides automatic facilities for double-precision addition and subtraction and for single-precision multiplication and division, all in fixed-point mode. The 168-2 Auxiliary Arithmetic Unit speeds the execution of floating-point arithmetic operations.

Although the basic 11-bit add time is only 19.2 microseconds, double-precision addition takes 225 microseconds using subroutines and 145 microseconds using the 168-1 Arithmetic Unit. Floating-point add times are about 4,000 microseconds using subroutines and 1,000 microseconds using the 168-2 Arithmetic Unit.

.2 HARDWARE (Contd.)

Simultaneous operations cannot be performed in Control Data 160 systems; the central processor is interlocked during all input-output operations. There is no interrupt system.

The principal input-output devices used with Control Data 160 systems are the built-in tape reader and punch and the following optional units:

- An on-line typewriter, which provides the typewriter input-output facilities that are lacking in the basic 160 system.
- A card reader, rated at either 250 or 1,200 cards per minute.
- A card punch, rated at either 100 or 200 cards per minute; the slower model is an IBM 523.
- A line printer with a rated speed of either 150 or 1,000 lines per minute.
- Up to four magnetic tape units. Either the 163 Magnetic Tape Subsystem or the newer 603 Magnetic Tape Units can be connected. Both use IBM 729-compatible tape in either BCD or binary mode. The 163 subsystem consists of one to four tape handlers and a control unit; its peak speed is 30,000 characters per second at a recording density of 200 rows per inch. The 603 has peak speeds of 15,000 or 41,667 characters per second at recording densities of 200 and 556 rows per inch, respectively.

A 160 computer can be connected on-line to a larger Control Data 1604, 1604-A, or 3000 Series computer. Data can be transferred between the coupled systems by direct core-to-core transfers or by way of shared magnetic tape units.

.3 SOFTWARE

Because of the Control Data 160's short word length and machine-language programming complexity, the software available for the system is of particular importance. A useful assortment of programming systems and subroutines, developed by Control Data and by 160 users, is now available, although many significant programs that have been developed for the 160-A cannot be run on 160 systems. The software facilities that are properly documented and in general use are supplied through a well-organized, CDC-supported users' group called SWAP.

OSAS is the basic symbolic assembly system for the 160 and 160-A. It provides no facilities for macro-instructions, but library subroutines can be assembled along with the user's source programs. Only about 250 symbolic labels can be accommodated by the OSAS translator for the 160. The translator is available in different versions for systems that use paper tape, magnetic tape, or punched card input-output.

A compiler is available for 160 FORTRAN, a restricted but useful version of the FORTRAN II language. The restrictions are imposed mainly by the hardware limitations of the 160 itself. Fixed-point arithmetic is limited to single precision (11 bits), while each floating-point variable occupies three words of core storage. Mixed-mode arithmetic is permitted. Object programs compiled by 160 FORTRAN are executed interpretively.

INTERFOR is a floating-point interpretive system for the 160. Its repertoire of 22 instructions is a subset of the larger Control Data 1604's machine-language instruction repertoire; thus, INTERFOR makes it easy for 1604 programmers to write programs that can be executed interpretively on a 160. Each floating-point data value occupies four words of 160 storage. Standard INTERFOR subroutines handle input, output, and mathematical functions. INTERFOR programs can be written directly in octal format, or they can be written in a more convenient symbolic format and assembled by FLAP, a special-purpose assembler.

Among the library subroutines available for the 160 are routines to perform single-precision multiplication and division, multiple-precision fixed-point arithmetic, decimal arithmetic, floating-point arithmetic, mathematical functions, radix conversions, matrix inversion, and data transcriptions (card-to-tape and tape-to-printer).



PRICE DATA: CONTROL DATA 160

The following prices are the list purchase, single-shift rental, and single-shift maintenance prices currently in effect for Control Data 160 equipment. In general, they are the same as the prices that were in effect while the 160 system was in production. It is likely that this equipment can now be obtained at lower prices.

CLASS	IDENTITY OF UNIT		PRICES		
	No.	Name	Monthly Rental \$	Monthly Maintenance \$	Purchase \$
CENTRAL PROCESSOR	160	Computer, including 4,096 words of core storage and paper tape reader and punch	1,500	200	60,000
	168-1	Auxiliary Arithmetic Unit (fixed point)	390	125	11,700
	168-2	Auxiliary Arithmetic Unit (floating point)	450	130	13,500
STORAGE		Included in basic Computer, above			
INPUT-OUTPUT	161	On-Line Input-Output Typewriter	262	95	10,500
	167-1	Card Reader (250 cpm)	400	140	15,700
	405	Card Reader (1200 cpm)	400	65	22,500
	177	Card Reader Controller (for 405)	100	10	4,800
	415	Card Punch (200 cpm)	295	60	18,150
	523	IBM Card Punch (100 cpm)	121	?	5,100
	170	Card Punch Controller (for 415 or 523)	335	55	13,700
	166-1	Line Printer (150 lpm)	595	275	25,000
	1612	Line Printer (1000 lpm)	1,840	400	73,500
	603	Magnetic Tape Unit	550	120	24,000
	162-1	Tape Synchronizer (for 1 to 4 603's)	500	105	20,000
		Magnetic Tape Subsystem:			
	163-1	One tape handler and control	970	235	38,800
	163-2	Two tape handlers and control	1,482	400	59,300
	163-3	Three tape handlers and control	1,994	565	79,800
	163-4	Four tape handlers and control	2,506	730	100,300
	165-1	Incremental Plotter	210	80	7,000